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909.9 Design fire. The design fire shall be based on a rational analysis performed by the registered design professional and approved by the fire code official. The design fire shall be based on the analysis in accordance with Section 909.4 and this section.

♦The design fire is the most critical element in the smoke control system design. The fire is what produces the smoke to be controlled by the system; thus, the size of the fire directly impacts the quantity of smoke being produced. This section ensures that the design fire be determined through a rational analysis by a registered design professional with knowledge in this area. Such professionals should have experience in the area of fire dynamics, fire engineering and general building design, including mechanical systems. When determining the design fire the designer should work with various stakeholders to determine the types of hazards and combustible materials (fire scenarios) on a permanent as well as temporary basis (i.e., Christmas/holiday decorative materials or scenery, temporary art exhibits) that may be present throughout the use of the building once occupied. Those hazards then need to be translated to potential design fires to be used when determining the smoke layer interface height for the duration as determined by Section 909.4.6. See the commentary for Section 909.9.3 for potential sources when determining design fires.

This section also does not mandate the type of fire (i.e., steady versus unsteady). A steady fire assumes a constant heat release rate over a period of time, where unsteady fires do not. An unsteady fire includes the growth and decay phases of the fire, as well as the peak heat release rate. An unsteady fire will hit a peak heat release rate when burning in the open, like an axisymmetric fire. An unsteady fire is a more realistic view of how fires actually burn. It should be noted that fires can be a combination of unsteady and steady fires when the sufficient fuel is available. In other words, the fire initially grows (unsteady) then reaches a steady state and burns for sometime at a particular heat release rate before decay occurs.

Design fire information should therefore typically include growth rate, peak heat release rate, duration and decay as well as information related to fire locations and products of combustion yield (CO, smoke, etc.) that are produced by the various design fires that are deemed credible for the space.

To provide an order of magnitude of fire sizes obtained from various combustibles, the following

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data from fire tests is provided. The following heat release rates, found in Section 3, Chapter 3-1 of the 2nd edition of the SFPE Handbook of Fire Protection Engineering, are peak heat release rates:

Plastic trash bags/paper trash: 114-332 Btu/sec (120-350 kw)

Latex foam pillow: 114 Btu/sec approximately (120 kw)

Dry Christmas tree: 475-618 Btu/sec (500-650 kw)

Sofa: 2,852 Btu/sec approximately (3,000 kw)

Plywood wardrobe: 2,947-6,084 Btu/sec (3,100-6,400 kw)

909.9.1 Factors considered. The engineering analysis shall include the characteristics of the fuel, fuel load, effects included by the fire, and whether the fire is likely to be steady or unsteady.

♦This section simply provides more detail on the factors that should be taken under consideration when determining the design fire size. To determine the appropriate fire size, an engineering analysis is necessary that takes into account the following elements:

fuel (potential burning rates), fuel load (how much), effects included by the fire (smoke particulate size and density), steady or unsteady (burn steadily or simply peak and dissipate) and likelihood of sprinkler activation (based on height and distance from the fire).

909.9.2 Design fire fuel. Determination of the design fire shall include consideration of the type of fuel, fuel spacing and configuration.

♦ The design fire size may also be affected by surrounding combustibles, which may have the effect of increasing the fire size. More specifically, there is concern that if sufficient separation is not maintained between combustibles, then a larger design fire is likely. The code does not provide extensive detail on this as such determination is left to the rational analysis undertaken by the design professional. NFPA 92B provides one method in which you determine the critical separation distance, R. This is based upon fire size and the critical radiant heat flux for nonpiloted ignition. Nonpiloted ignition means the radiated heat from the fire without direct flame contact will ignite adjacent combustibles.

909.9.3 Heat-release assumptions. The analysis shall make use of best available data from approved sources and shall not be based on excessively stringent limitations of combustible material.

♦This section is merely

stressing the fact that data obtained for use in a rational analysis needs to come from relevant and appropriate sources. Data can be obtained from groups such as the NIST or from Annex B of NFPA 92B. Data from fire tests is available and is a good resource for such analysis. As noted earlier, such data is not prevalent (see also Chapter 8, Analysis of Design Fires of the Guide to Smoke Control in the 2006 IBC and Section 3, Chapter 3-1 of the SFPE Handbook of Fire Protection Engineering).

909.9.4 Sprinkler effectiveness assumptions. A documented engineering analysis shall be provided for conditions that assume fire growth is halted at the time of sprinkler activation.

♦This section raises a few questions regarding activation of sprinklers and their impact on the fire both in terms of their ability to "control" as well as "extinguish" a fire. The first is concerning an assumption that sprinklers will immediately control the fire as soon as they are activated (i.e., control results in limiting further growth and maintaining the heat release rate at approximately the same fire size as when the sprinklers activated). This assumption may be true in some cases, but for high ceilings the sprinkler may not activate or may be ineffective. Sprinklers may be ineffective in high spaces, since by the time they are activated the fire is too large to control. Essentially, the fire plume may push away and evaporate the water before it actually reaches the seat of the fire.

Additionally the fire may be shielded from sprinkler spray so that insufficient quantities of water reach the fuel. These are common problems with high-piled storage as well as other fires including retail and has been shown in actual tests. Also, if the fire becomes too large before the sprinklers are activated, the available water supply and pressure for the system may be compromised. Additionally, based on the layout of the room and the movement of the fire effluents, the wrong sprinklers could be activated, which leads to a larger fire size and depletion of the available water supply and pressure.

Another issue is whether the sprinklers "control" or "extinguish" the fire. Typical sprinklers are assumed only to control fires as opposed to extinguishing them. Sprinklers may be able to extinguish the fire, but it should not automatically be assumed. A fire that is controlled will achieve steady state and maintain a certain fire size, which is very different from a fire that is actually extinguished.

Based upon these concerns, each scenario needs to be looked at individually to

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determine whether sprinklers would be effective in halting the growth or extinguishing the fire. More specifically, the evaluation should include droplet size, density and area of coverage and should also be based on actual test results.

909.10 Equipment. Equipment including, but not limited to, fans, ducts, automatic dampers and balance dampers shall be suitable for their intended use, suitable for the probable exposure temperatures that the rational analysis indicates, and as approved by the fire code official.

♦ Section 909.10 and subsequent sections are primarily related to the reliability of the system components to provide a smoke control system that works according to the design. One of the largest concerns when using smoke control provisions is the overall reliability of the system. Such systems have many different components, such as smoke and fire dampers; fans; ducts and controls associated with such components.

The more components a system has, the less reliable it becomes. In fact, one approach in providing a higher level of reliability is utilizing the normal building systems such as the HVAC to provide the smoke control system. Basically, systems used every day are more likely to be working appropriately, since they are essentially being tested daily; however, there are many components that are specific to the smoke control system, such as exhaust fans in an atrium or the smoke control panel.

Also, there is not a generic prescriptive set of requirements as to how all smoke control system elements should operate, since each design may be fairly unique. The specifics on operation of such a system need to be included within the design and construction documents. Most components used in smoke control systems are elements used in many other applications such as HVAC systems; therefore, the basic mechanisms of a fan used in a smoke control system may not be different, although they may be applied differently.

909.10.1 Exhaust fans. Components of exhaust fans shall be rated and certified by the manufacturer for the probable temperature rise to which the components will be exposed. This temperature rise shall be computed by:

$$T_s = (Q_c / mc) + (T_a)$$ (Equation 9-3)

where:

c = Specific heat of smoke at smokelayer temperature,

Btu/lb°F · (kJ/kg · K).

m = Exhaust rate, pounds per second (kg/s).

Q_c = Convective heat output

of fire, Btu/s (kW).

Ta = Ambient temperature, °F (K).

Ts = Smoke temperature, °F (K).

Exception: Reduced Ts as calculated based on the assurance of adequate dilution air.

♦Fans used for smoke control systems must be able to tolerate the possible elevated temperatures to which they will be exposed. Again, like many other factors this depends upon the specifics of the design fire.

Essentially, Equation 9-3 requires the calculation of the potential temperature rise. The exhaust fans must be specifically rated and certified by the manufacturer to be able to handle these rises in temperature. There is an exception that allows reduction of the temperature if it can be shown that adequate temperature reduction will occur. In many cases if the exhaust fans are near the ceiling, the smoke will be much cooler than the value resulting from Equation 9-3 since the smoke may cool considerably by the time it reaches the ceiling. Also, sprinkler activation will assist in cooling the smoke further.

909.10.2 Ducts. Duct materials and joints shall be capable of withstanding the probable temperatures and pressures to which they are exposed as determined in accordance with Section 909.10.1. Ducts shall be constructed and supported in accordance with the International Mechanical Code. Ducts shall be leak tested to 1.5 times the maximum design pressure in accordance with nationally accepted practices. Measured leakage shall not exceed 5 percent of design flow. Results of such testing shall be a part of the documentation procedure.

Ducts shall be supported directly from fire-resistance-rated structural elements of the building by substantial, noncombustible supports.

Exception: Flexible connections (for the purpose of vibration isolation) complying with the International Mechanical Code and which are constructed of approved fire resistance-rated materials.

♦The next essential component of a smoke control system is the integrity of the ducts to transport supply and exhaust air. The integrity of ducts is also important for an HVAC system, but is more critical in this case since it is not simply a comfort issue but one of life safety. The key concern with ducts in smoke control systems is that they can withstand elevated temperatures and that there will be minimal leakage. The concern with leakage is the potential of leaking smoke into another smoke zone or not providing the proper amount of supply air to

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support the system.

More specifically, all ducts need to be leak tested to 1.5 times the maximum static design pressure. The leakage resulting should be no more than 5 percent of the design flow. For example, a duct that has a design flow of 300 cubic feet per minute (cfm) (0.141 m3/s) would be allowed 15 cfm (0.007 m3/s) of leakage when exposed to a pressure equal to 1.5 times the design pressure for that duct. The tests should be in accordance with nationally accepted practices.

This criterion will often limit ductwork for smoke control systems to lined systems, since the amount of leakage in such systems is much less.

As part of the concern for possible exposure to fire and fire products, the ducts are required to be supported by way of substantial noncombustible supports connected to the fire-resistance-rated structural elements of the building. As noted, the system needs to able to run for 20 minutes starting from the detection of the fire. The supports are allowed to be other than noncombustible when they are flexible connections provided to mitigate the effects of vibration, perhaps as part of a building exposed to seismic loads.

The flexible connections still need to be constructed of approved fire-resistance-rated materials.

NFPA 92B also references NFPA 90A for ducts conveying smoke and is part of the design requirements for exhaust systems.

As part of the concern for possible exposure to fire and fire products, the ducts are required to be supported by way of substantial noncombustible supports connected to the fire-resistance-rated structural elements of the building. As noted, the system needs to able to run for 20 minutes starting from the detection of the fire. The exception to this section is really more of an acknowledgement that flexible connections for vibration isolation are acceptable when constructed of approved fire-resistance-rated materials.

More specifically, it is often necessary to use such connections for connecting the duct to the fan. These connections cannot necessarily meet the requirements of the main section, but are a minimal part of the ductwork and as long as they perform adequately with regard to fire resistance they are permitted. Note that the term "approved" is used to determine the required fire resistance, therefore, flexibility is provided.

The code does not specifically address this determination but perhaps a relationship to the duration or operation and these flexible

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connections could be made to determine the necessary performance.

909.10.3 Equipment, inlets and outlets. Equipment shall be located so as to not expose uninvolved portions of the building to an additional fire hazard. Outside air inlets shall be located so as to minimize the potential for introducing smoke or flame into the building. Exhaust outlets shall be so located as to minimize reintroduction of smoke into the building and to limit exposure of the building or adjacent buildings to an additional fire hazard.

♦The intent of this section is to minimize the likelihood of smoke being reintroduced into the building due to poorly placed outdoor air inlets and exhaust air outlets; therefore, placing one right next to another on temperature rise to which the components will be exposed. This temperature rise shall be computed by:

$T_s = (Q_c / mc) + (T_a)$ (Equation 9-3)

where:

c = Specific heat of smoke at smoke layer temperature,

Btu/lb°F · (kJ/kg · K).

m = Exhaust rate, pounds per second (kg/s).

Q_c = Convective heat output of fire, Btu/s (kW).

T_a = Ambient temperature, °F (K).

T_s = Smoke temperature, °F (K).

Exception: Reduced T_s as calculated based on the assurance of adequate dilution air.

♦Fans used for smoke control systems must be able to tolerate the possible elevated temperatures to which they will be exposed. Again, like many other factors this depends upon the specifics of the design fire.

Essentially, Equation 9-3 requires the calculation of the potential temperature rise. The exhaust fans must be specifically rated and certified by the manufacturer to be able to handle these rises in temperature. There is an exception that allows reduction of the temperature if it can be shown that adequate temperature reduction will occur. In many cases if the exhaust fans are near the ceiling, the smoke will be much cooler than the value resulting from Equation 9-3 since the smoke may cool considerably by the time it reaches the ceiling. Also, sprinkler activation will assist in cooling the smoke further.

909.10.2 Ducts. Duct materials and joints shall be capable of withstanding the probable temperatures and pressures to which they are exposed as determined in accordance with Section 909.10.1. Ducts shall be constructed and supported in accordance with the International Mechanical

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Code. Ducts shall be leak tested to 1.5 times the maximum design pressure in accordance with nationally accepted practices. Measured leakage shall not exceed 5 percent of design flow. Results of such testing shall be a part of the documentation procedure.

Ducts shall be supported directly from fire-resistance-rated structural elements of the building by substantial, noncombustible supports.

Exception: Flexible connections (for the purpose of vibration isolation) complying with the International Mechanical Code and which are constructed of approved fire resistance-rated materials.

♦The next essential component of a smoke control system is the integrity of the ducts to transport supply and exhaust air. The integrity of ducts is also important for an HVAC system, but is more critical in this case since it is not simply a comfort issue but one of life safety. The key concern with ducts in smoke control systems is that they can withstand elevated temperatures and that there will be minimal leakage. The concern with leakage is the potential of leaking smoke into another smoke zone or not providing the proper amount of supply air to support the system.

More specifically, all ducts need to be leak tested to 1.5 times the maximum static design pressure. The leakage resulting should be no more than 5 percent of the design flow. For example, a duct that has a design flow of 300 cubic feet per minute (cfm) (0.141 m3/s) would be allowed 15 cfm (0.007 m3/s) of leakage when exposed to a pressure equal to 1.5 times the design pressure for that duct. The tests should be in accordance with nationally accepted practices.

This criterion will often limit ductwork for smoke control systems to lined systems, since the amount of leakage in such systems is much less.

As part of the concern for possible exposure to fire and fire products, the ducts are required to be supported by way of substantial noncombustible supports connected to the fire-resistance-rated structural elements of the building. As noted, the system needs to able to run for 20 minutes starting from the detection of the fire. The supports are allowed to be other than noncombustible when they are flexible connections provided to mitigate the effects of vibration, perhaps as part of a building exposed to seismic loads.

The flexible connections still need to be constructed of approved fire-resistance-rated materials.

NFPA 92B also references NFPA 90A for ducts conveying smoke and is part of the design requirements for exhaust systems.

As part of the concern for possible exposure to fire and fire products, the ducts are required to be supported by way of substantial noncombustible supports connected to the fire-resistance-rated structural elements of the building. As noted, the system needs to able to run for 20 minutes starting from the detection of the fire. The exception to this section is really more of an acknowledgement that flexible connections for vibration isolation are acceptable when constructed of approved fire-resistance-rated materials.

More specifically, it is often necessary to use such connections for connecting the duct to the fan. These connections cannot necessarily meet the requirements of the main section, but are a minimal part of the ductwork and as long as they perform adequately with regard to fire resistance they are permitted. Note that the term "approved" is used to determine the required fire resistance, therefore, flexibility is provided.

The code does not specifically address this determination but perhaps a relationship to the duration or operation and these flexible connections could be made to determine the necessary performance.

909.10.3 Equipment, inlets and outlets. Equipment shall be located so as to not expose uninvolved portions of the building to an additional fire hazard. Outside air inlets shall be located so as to minimize the potential for introducing smoke or flame into the building. Exhaust outlets shall be so located as to minimize reintroduction of smoke into the building and to limit exposure of the building or adjacent buildings to an additional fire hazard.

♦The intent of this section is to minimize the likelihood of smoke being reintroduced into the building due to poorly placed outdoor air inlets and exhaust air outlets; therefore, placing one right next to another on the exterior of the building would be inappropriate.

Additionally, wind and other adverse conditions should be considered when choosing locations for these inlets and outlets. Particular attention should be paid to introducing exhausted smoke into another smoke zone. Also, smoke should be exhausted in a direction that will not introduce it into surrounding buildings or facilities. Within the building itself, the supply air and exhaust outlets should also be strategically located. The exhaust inlets and supply air should be evenly distributed to reduce the likelihood of a high velocity of air that may disrupt the fire plume and also push smoke back into occupied areas. See

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the commentary for Section 909.8 for discussion on avoiding plugholing.

909.10.4 Automatic dampers. Automatic dampers, regardless of the purpose for which they are installed within the smoke control system, shall be listed and conform to the requirements of approved recognized standards.

♦ This section addresses the reliability of any dampers used within a smoke control system. This particular provision requires that the dampers be listed and conform to the appropriate recognized standards.

More specifically, Section 717 of the IBC contains more detailed information on the specific requirements for smoke and fire dampers. Smoke and fire dampers should be listed in accordance with UL 555S and 555, respectively. Also, remember that each smoke control design is unique and the sequence and methods used to activate the dampers may vary from design to design. This information needs to be addressed in the construction documents.

Another factor to take into account, with regard to timing of the system, is the fact that some dampers react more quickly than others, simply due to the particular smoke damper characteristics. Additionally, during the commissioning of the system, the damper is going to be exposed to many repetitions. These repetitions need to be accounted for in the overall reliability of the system.

909.10.5 Fans. In addition to other requirements, belt-driven fans shall have 1.5 times the number of belts required for the design duty with the minimum number of belts being two.

Fans shall be selected for stable performance based on normal temperature and, where applicable, elevated temperature.

Calculations and manufacturer's fan curves shall be part of the documentation procedures. Fans shall be supported and restrained by noncombustible devices in accordance with the structural design requirements of Chapter 16 of the International Building Code.

Motors driving fans shall not be operated beyond their nameplate horsepower (kilowatts) as determined from measurement of actual current draw and shall have a minimum service factor of 1.15.

♦Part of the overall reliability requires that fans used to provide supply air and exhaust capacity will be functioning when necessary; therefore, a safety factor of 1.5 is placed upon the required belts for fans. All fans used as part of a smoke control system must provide

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1.5 times the number of required belts with a minimum of two belts for all fans.

This section also points out that the fan chosen should fit the specific application. It should be able to withstand the temperature rise as calculated in Section 909.10.1 and generally be able to handle typical exposure conditions, such as location and wind. For instance, propeller fans are highly sensitive to the effects of wind. When located on the windward side of a building, wall-mounted, nonhooded propeller fans are not able to compensate for wind effects.

Additionally, even hooded propeller fans located on the leeward side of the building may not adequately compensate for the decrease in pressure caused by wind effects. In general, when designing a system, it should be remembered that field conditions might vary from the calculations; therefore, flexibility should be built into the design that would account for things, such as variations in wind conditions.

Finally, this section stresses that fan motors not be operated beyond their rated horsepower.

909.11 Power systems. The smoke control system shall be supplied with two sources of power. Primary power shall be from the normal building power systems. Secondary power shall be from an approved standby source complying with Section 604 and NFPA 70. The standby power source and its transfer switches shall be in a room separate from the normal power transformers and switch gears and ventilated directly to and from the exterior. The room shall be enclosed with not less than 1-hour fire barriers constructed in accordance with Section 707 of the International Building Code or horizontal assemblies constructed in accordance with Section 711 of the International Building Code, or both. The transfer to full standby power shall be automatic and within 60 seconds of failure of the primary power.

♦ As with any life safety system, a level of redundancy with regard to power supply is required to enable the functioning of the system during a fire. The primary source is the building's normal power system. The secondary power system is by means of standby power. One of the key elements is that standby power systems are intended to operate within 60 seconds of loss of primary power. It should be noted that the primary difference between standby power and emergency power is that emergency power must operate within 10 seconds of loss of primary power versus 60 seconds. This section also requires isolation from normal building power systems via a 1-hour fire

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barrier or 1-hour horizontal assembly or both depending upon the location within the building. This increases the reliability and reduces the likelihood that a single event could remove both power supplies.

909.11.1 Power sources and power surges. Elements of the smoke control system relying on volatile memories or the like shall be supplied with uninterruptable power sources of sufficient duration to span 15-minute primary power interruption.

Elements of the smoke control system susceptible to power surges shall be suitably protected by conditioners, suppressors or other approved means.

♦Smoke control systems have many components, sometimes highly sensitive electronics, that are adversely affected by any interruption in or sudden surges of power. Therefore, Section 909.11.1 requires that any components of a smoke control system, such as volatile memories, be supplied with an uninterruptible power system for the first 15 minutes of loss of primary power. Volatile memory components will lose memory upon any loss of power no matter how short the time period. Once the 15 minutes elapses, these elements can be transitioned to the already operating standby power supply.

With regard to components sensitive to power surges, they need to be provided with surge protection in the form of conditioners, suppressors or other approved means.

909.12 Detection and control systems. Fire detection systems providing control input or output signals to mechanical smoke control systems or elements thereof shall comply with the requirements of Section 907. Such systems shall be equipped with a control unit complying with UL 864 and listed as smoke control equipment.

Control systems for mechanical smoke control systems shall include provisions for verification. Verification shall include positive confirmation of actuation, testing, manual override, the presence of power downstream of all disconnects and, through a preprogrammed weekly test sequence, report abnormal conditions audibly, visually and by printed report.

♦This section is focused upon two main elements. The first is the proper operation and monitoring of the fire detection system that activates the smoke control system through compliance with Section 907 and UL 864. This requires a specific listing as smoke control equipment. UL 864 has a subcategory (UUKL) specific to fire alarm control panels for smoke control system applications.

The second aspect is related

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to the mechanical elements of the smoke control system once the system is activated. In particular, there is a focus upon verification of activities. Verification would include the following two aspects according to the second paragraph of this section:

1. The system is able to verify actuations, testing, manual overrides and the presence of power downstream. This would require information reported back to the smoke control panel, which can be accomplished via the weekly test sequence or through full electronic monitoring of the system.

2. Conduct a preprogrammed weekly test that simulates an actual (smoke) event to test the components of the system. These components would include elements such as smoke dampers, fans and doors. Abnormal conditions need to be reported in three ways:

a. Audibly;

b. Visually; and

c. Printed report.

It should be noted that electrical monitoring of the control components is not required (supervision).

Such supervision verifies integrity of the conductors from a fire alarm control unit to the control system input. The weekly test is considered sufficient verification of system performance and is often termed end to end verification. In other words the control system input provides the expected results. Verification can be accomplished through any sensor that be calibrated to distinguish between the difference between proper operation and a fault condition. For fans, proper operations mean that the fan is moving air within the intent of its design. Fault conditions include power failure, broken fan belts, adverse wind effects, a locked rotor condition and/or filters or large ducts that are blocked causing significantly reduced airflow.

In addition to differential pressure transmitters and sail switches this can be accomplished by the present state of the current sensors. More discussion on verification for elements such as ducts and fire doors is discussed in Chapter 9 of A Guide to Smoke Control in the 2006 IBC.

Also, the fact that a smoke control system is nondedicated (integrated with an HVAC system) does not mean that it is automatically being tested on a daily basis. It is cautioned that simply depending upon occupant discomfort, for example, is sometimes an insufficient indicator of a fully functioning smoke control system. There may be various modes in which the HVAC system could operate that may not exercise the smoke control features and the sequence in which the system should operate. An example is an air-conditioning system operating only in full recirculating mode versus exhaust mode. This failure will likely not affect occupants and will not exercise the exhaust function. Plus, doors, which may be part of the smoke barrier, may not need to be closed in normal building operations but would need to be closed during smoke control system operation. This is why this section does not necessarily differentiate between dedicated and nondedicated smoke control systems and requires the system components to be tested.

It is important to note that this weekly test sequence is not an actual smoke event and is only intended to activate the system to ensure that the components are working correctly.

Although NFPA 92B is only referenced for design Sections 7.3.1 and 7.3.8 of that standard coordinate with this section. More specifically, Section 7.3.8 also requires the weekly test but as provided for by the UL864-UUKL-listed smoke control panel. NFPA 92B Section 7.3.6.2 requires off-normal indication at the smoke control panel within 200 seconds when a positive confirmation is failed to be achieved. Section 909.12 only requires that abnormal conditions be reported weekly.

909.12.1 Wiring. In addition to meeting requirements of NFPA 70, all wiring, regardless of voltage, shall be fully enclosed within continuous raceways.

♦Wiring is required to be placed within continuous raceways which provides an additional level of reliability for the system. The definition of the term “raceway” in NFPA 70 lists several acceptable types of complying raceway that can be used, however manufactured cable assemblies such as metal-clad cable (Type MC) or armored cable (Type AC) are not included.

909.12.2 Activation. Smoke control systems shall be activated in accordance with this section.

♦The activation of a smoke control system is dependent on when such a system is required. Mechanical smoke control systems, which could include pressurization, airflow or exhaust methods, require an automatic activation mechanism. When using a passive system, which depends upon compartmentation, spot-type detectors are acceptable for the release of door closers and similar openings. Whereas with more complex mechanical system such activation needs to go beyond single station detectors and be part of an automatic coordinated system.

909.12.2.1 Pressurization,

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airflow or exhaust method. Mechanical smoke control systems using the pressurization, airflow or exhaust method shall have completely automatic control.

♦ Automatic activation of such systems is especially critical as tenability is much more difficult to achieve if a delay occurred waiting for manual activation of the system. See Sections 909.6 for the pressurization method, 909.7 for the airflow design method and 909.8 for the exhaust method.

909.12.2.2 Passive method. Passive smoke control systems actuated by approved spot-type detectors listed for releasing service shall be permitted.

♦This section recognizes that a passive system does not address smoke containment through mechanical means; therefore, it does not need to be "automatically activated" except in cases where smoke barriers have openings. These openings would be required to have smoke detectors to close openings where required by the design. Although spot type detectors are technically automatic they are not part of a more coordinated system of activation as needed for mechanical smoke control systems. Such detectors are simply standalone devices that fail in the fail safe position. In other words if the power were lost a door on a magnetic hold would simply close.

909.12.3 Automatic control. Where completely automatic control is required or used, the automatic-control sequences shall be initiated from an appropriately zoned automatic sprinkler system complying with Section 903.3.1.1, manual controls that are readily accessible to the fire department, and any smoke detectors required by the engineering analysis.

♦When automatic activation is required, it must be accomplished by a properly zoned automatic sprinkler system and, if the engineering analysis requires them, smoke detectors. Manual control for the fire department needs to be provided. An important point with this particular requirement is that smoke control systems are engineered systems and a prescribed smoke detection system may not fit the needs of the specific design. Other types of detectors, such as beam detectors (within an atrium), may be used and could be more useful and be more practical from a maintenance standpoint. Also, it may not be practical or appropriate for the building's fire alarm system to activate such systems as it may alter the effectiveness of the system by pulling smoke through the building versus removing or containing the smoke.

For example, a building with an atrium may have several

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floors below the space. If a fire occurs in one of the floors not associated with the atrium the atrium smoke control system could possibly pull smoke throughout the building if the detection is zoned incorrectly.

909.13 Control air tubing. Control air tubing shall be of sufficient size to meet the required response times. Tubing shall be flushed clean and dry prior to final connections and shall be adequately supported and protected from damage. Tubing passing through concrete or masonry shall be sleeved and protected from abrasion and electrolytic action.

♦Control tubing is a method that uses pneumatics to operate components such as the opening and closing of dampers. Due to the sophistication of electronic systems today, control tubing is becoming less common.

These particular requirements provide the criteria for properly designing and installing control tubing.

Essentially, it is up to the design professional to determine the size requirements and to properly design appropriate supports. This information needs to be detailed within the construction documents.

Additionally, due to the effect of moisture and other contaminants on control tubing, it must be flushed clean then dried before installation.

909.13.1 Materials. Control air tubing shall be hard drawn copper, Type L, ACR in accordance with ASTM B 42, ASTM B 43, ASTM B 68, ASTM B 88, ASTM B 251 and ASTM B 280. Fittings shall be wrought copper or brass, solder type, in accordance with ASME B 16.18 or ASME B 16.22. Changes in direction shall be made with appropriate tool bends. Brass compression-type fittings shall be used at final connection to devices; other joints shall be brazed using a BCuP5 brazing alloy with solidus above 1,100°F (593°C) and liquidus below 1,500°F (816°C). Brazing flux shall be used on copper-to-brass joints only.

Exception: Nonmetallic tubing used within control panels and at the final connection to devices, provided all of the following conditions are met:

1. Tubing shall comply with the requirements of Section 602.2.1.3 of the International Mechanical Code .

2. Tubing and the connected device shall be completely enclosed within a galvanized or paint-grade steel enclosure having a minimum thickness of 0.0296 inch (0.7534 mm) (No.22 gage). Entry to the enclosure shall be by copper tubing with a protective grommet of neoprene or Teflon or by suitable brass compression to male-barbed

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adapter.

3. Tubing shall be identified by appropriately documented coding.

4. Tubing shall be neatly tied and supported within enclosure. Tubing bridging cabinet and door or moveable device shall be of sufficient length to avoid tension and excessive stress. Tubing shall be protected against abrasion. Tubing serving devices on doors shall be fastened along hinges.

♦This section addresses the materials allowed for control air tubing along with approved methods of connection.

All of this information needs to be documented, as it will be subject to review by the special inspector.

909.13.2 Isolation from other functions. Control tubing serving other than smoke control functions shall be isolated by automatic isolation valves or shall be an independent system.

♦This section requires separation of control tubing used for other functions through the use of isolation valves or a completely separate system. This is due to the difference in requirements for control tubing used in a smoke control system versus other building systems. The isolation of the control air tubing for a smoke control system needs to be specifically noted on the construction documents.

909.13.3 Testing. Control air tubing shall be tested at three times the operating pressure for not less than 30 minutes without any noticeable loss in gauge pressure prior to final connection to devices.

♦As part of the acceptance testing of the smoke control system, the control air tubing will be pressure tested three times the operating pressure for 30 minutes or more. The performance criteria as to whether the control tubing is considered a failure is when there is any noticeable loss in gauge pressure prior to final connection of devices during the 30-minute duration test.

909.14 Marking and identification. The detection and control systems shall be clearly marked at all junctions, accesses and terminations.

♦This section requires that all portions of the fire detection system that activate the smoke control system be marked and identified appropriately. This includes all applicable fire alarm-initiating devices, the respective junction boxes, all data-gathering panels and fire alarm control panels. Additionally, all components of the smoke control system, which are not considered a fire detection system, are required to be properly identified and marked. This would include all applicable junction boxes, control

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tubing, temperature control modules, relays, damper sensors, automatic door sensors and air movement sensors.

909.15 Control diagrams. Identical control diagrams showing all devices in the system and identifying their location and function shall be maintained current and kept on file with the fire code official , the fire department and in the fire command center in a format and manner approved by the fire chief.

♦The purpose of control diagrams is to provide consistent information on the system in several key locations, including the building department, the fire department and the fire command center. If a fire command center is not required or provided, the diagrams need to be located such that they can be readily accessed during an emergency. Some possible locations may be the security office, the building manager's office or, if possible, within the smoke control panel. This information is intended to assist in the use and operation of the smoke control system. The format of the control diagram is as approved by the fire chief. This is necessary since the fire department is the agency that will be using such a system during a fire and when the system is tested in the future. The more clearly the information is communicated, the more effective the smoke control system will be.

It should be noted that the fire department may want all smoke control systems within a jurisdiction to follow a particular protocol for control diagrams. Generally, the control diagrams should indicate the required reaction of the system in all scenarios. The status or position of every fan and damper in every scenario must be clearly identified.

909.16 Fire-fighter's smoke control panel. A fire-fighter's smoke control panel for fire department emergency response purposes only shall be provided and shall include manual control or override of automatic control for mechanical smoke control systems. The panel shall be located in a fire command center complying with Section 508 in high-rise buildings or buildings with smoke-protected assembly seating.

In all other buildings, the fire-fighter's smoke control panel shall be installed in an approved location adjacent to the fire alarm control panel. The fire-fighter's smoke control panel shall comply with Sections 909.16.1 through 909.16.3.

♦One of the elements that makes a smoke control system effective is that its activity is successfully communicated to the fire department and the fire department is able to

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manually operate the system. The following sections provide requirements for a control panel specifically for smoke control systems. This panel is required to be located within a fire command center when it is located in a high-rise building or there is smoke-protected seating. Section 403.4.5 of the IBC would require a fire command center for high-rise buildings. Smoke-protected seating does not require a fire command center in Chapter 10 but this provision would ensure that one exists and contains the smoke control panel. Facilities with smoke-protected seating tend to be larger facilities that, at the very least, would already have a central security center if not a fire command center as required by the jurisdiction.

All other locations would only need to provide the panel in an approved location as long as it is located with the fire alarm panel. The specific location will depend on the needs of the fire department in that jurisdiction. The reason not all fire-fighter smoke control panels need to be located in a fire command center is that many smoke control systems are located in a building containing an atrium that may only be three stories in height. A 200-square-foot (19 m2) fire command center would be excessive for such buildings.

There are two components that include the requirements for the display and for the controls. This control panel will provide an ability to override any other controls whether manual or automatic within the building as they relate to the smoke control system.

Note that the publication Guide to Smoke Control in the 2006 IBC goes into more detail about the fire fighter smoke control panel requirements.

909.16.1 Smoke control systems. Fans within the building shall be shown on the fire-fighter's control panel. A clear indication of the direction of airflow and the relationship of components shall be displayed. Status indicators shall be provided for all smoke control equipment, annunciated by fan and zone and by pilot-lamp-type indicators as follows:

1. Fans, dampers and other operating equipment in their normal status—WHITE.

2. Fans, dampers and other operating equipment in their off or closed status—RED.

3. Fans, dampers and other operating equipment in their on or open status—GREEN.

4. Fans, dampers and other operating equipment in a fault status—YELLOW/AMBER.

♦This section denotes what should be displayed on the control panel. The display is

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required to include all fans, an indication of the direction of airflow and the relationship of the components. Also, status lights are required, and this section sets out specific standardized colors to indicate normal status, closed status, open status and fault status. A standardized approach increases the likelihood that the fire department will be able to quickly become familiar with a system. Since the fire department has the ability to override the automatic functions of the system, this information is critical.

909.16.2 Smoke control panel. The fire-fighter's control panel shall provide control capability over the complete smoke-control system equipment within the building as follows:

1. ON-AUTO-OFF control over each individual piece of operating smoke control equipment that can also be controlled from other sources within the building. This includes stairway pressurization fans; smoke exhaust fans; supply, return and exhaust fans; elevator shaft fans; and other operating equipment used or intended for smoke control purposes.

2. OPEN-AUTO-CLOSE control over individual dampers relating to smoke control and that are also controlled from other sources within the building.

3. ON-OFF or OPEN-CLOSE control over smoke control and other critical equipment associated with a fire or smoke emergency and that can only be controlled from the fire-fighter's control panel.

Exceptions:

1. Complex systems, where approved , where the controls and indicators are combined to control and indicate all elements of a single smoke zone as a unit.

2. Complex systems, where approved , where the control is accomplished by computer interface using approved , plain English commands.

♦This section sets the requirements as to which controls need to be provided for the fire department on the control panel.

There are two aspects to the controls. The controls will include on-auto-off and open-auto-close settings or will be strictly on-off or open-close. If the system or component can be set on automatic (auto), it can be controlled from other locations beyond the fire command center. This would include an automatic smoke detection system or by manual activation. If a control only contains on-off or open-close settings, the only way the system component can be controlled is in the fire command center.

It should be noted that components such as fans are

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usually associated with on-off-type controls, whereas components such as dampers are associated with open-close-type controls.

909.16.3 Control action and priorities. The fire-fighter's control panel actions shall be as follows:

1. ON-OFF and OPEN-CLOSE control actions shall have the highest priority of any control point within the building. Once issued from the fire-fighter's control panel, no automatic or manual control from any other control point within the building shall contradict the control action. Where automatic means are provided to or produce a specific result to safeguard the building or equipment (i.e., duct freezestats, duct smoke detectors, high-temperature cutouts, temperature-actuated linkage and similar devices), such means shall be capable of being overridden by the fire-fighter's control panel. The last control action as indicated by each firefighter's control panel switch position shall prevail. In no case shall control actions require the smoke control system to assume more than one configuration at any one time.

Exception: Power disconnects required by NFPA 70.

2. Only the AUTO position of each three-position firefighter's control panel switch shall allow automatic or manual control action from other control points within the building. The AUTO position shall be the NORMAL, nonemergency, building control position. Where a fire-fighter's control panel is in the AUTO position, the actual status of the device (on, off, open, closed) shall continue to be indicated by the status indicator described above. When directed by an automatic signal to assume an emergency condition, the NORMAL position shall become the emergency condition for that device or group of devices within the zone. In no case shall control actions require the smoke control system to assume more than one configuration at any one time.

This section clarifies that when a component of the system is placed in an on-off or open-close configuration, no other control point in the building, whether automatic or manual, can override the action established in the fire command center. If a system component is configured in auto mode, it can be controlled from locations within the building beyond the fire command center. Some controls are specifically designed to only allow an action from the fire command center.

909.17 System response time. Smoke-control system activation shall be initiated immediately after receipt of an appropriate automatic or

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manual activation command. Smoke control systems shall activate individual components (such as dampers and fans) in the sequence necessary to prevent physical damage to the fans, dampers, ducts and other equipment.

For purposes of smoke control, the fire-fighter's control panel response time shall be the same for automatic or manual smoke control action initiated from any other building control point. The total response time, including that necessary for detection, shutdown of operating equipment and smoke control system startup, shall allow for full operational mode to be achieved before the conditions in the space exceed the design smoke condition. The system response time for each component and their sequential relationships shall be detailed in the required rational analysis and verification of their installed condition reported in the required final report.

♦This particular section provides the criteria as to when the smoke control system is required to begin operation. Whether or not the activation is manual or automatic, this criteria clarifies that the system be initiated immediately. Also, it requires that components activate in a sequence that will not potentially damage the fans, dampers, ducts and other equipment.

Unrealistic timing of the system has the potential of creating an unsuccessful system. Delays in the system can be seen in slow dampers, fans that ramp up or down, systems that poll slowly and intentional built-in delays. These factors can add significantly to the reaction time of the system and may hamper achieving the design goals.

The key element is that the system be fully operational before the smoke conditions exceed the design parameters. The design should include these possible delays when analyzing the smoke layer interface location. The sequence of events need to be justified within the design analysis and described clearly in the construction documents.

909.18 Acceptance testing. Devices, equipment, components and sequences shall be individually tested. These tests, in addition to those required by other provisions of this code, shall consist of determination of function, sequence and, where applicable, capacity of their installed condition.

♦ In order to achieve a certain level of performance, the smoke control system needs to be thoroughly tested.

Section 909.18 requires that all devices, equipment components and sequences be individually tested.

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909.18.1 Detection devices. Smoke or fire detectors that are a part of a smoke control system shall be tested in accordance with Chapter 9 in their installed condition. When applicable, this testing shall include verification of airflow in both minimum and maximum conditions.

♦Detection devices are required to be tested in accordance with the fire protection requirements found in Chapter 9. Also, since such detectors may be subject to higher air velocities than typical detectors, their operation needs to be verified in the minimum and maximum anticipated airflow conditions.

909.18.2 Ducts. Ducts that are part of a smoke control system shall be traversed using generally accepted practices to determine actual air quantities.

♦This section requires ducts that are part of the smoke control system to be tested to show that the proper amount of air is flowing. It should be noted that Section 909.10.2 requires that the ducts be leak tested to 1.5 times the maximum design pressure. Such leakage is not allowed to exceed 5 percent of the design flow.

909.18.3 Dampers. Dampers shall be tested for function in their installed condition.

♦This section notes that all dampers need to be inspected to meet the function for which they are installed. For instance, a damper that is to be open when the system is in smoke control mode should be verified to be open when testing the system. Also, a damper may have a specific timing associated with its operation that would need to be verified though testing 909.18.4 Inlets and outlets. Inlets and outlets shall be read using generally accepted practices to determine air quantities.

♦ Similar to ducts, the appropriate amount of air that is entering or exiting the inlets and outlets, respectively, must be checked.

909.18.5 Fans. Fans shall be examined for correct rotation.

Measurements of voltage, amperage, revolutions per minute and belt tension shall be made.

♦This section requires the testing of fans for the following: correct rotation, voltage, amperage, revolutions per minute and belt tension. These features are key in having the system run as designed.

A common problem with fans is that they are often installed in the reverse direction. Also, to verify the reliability of the fans, elements such as the appropriate voltage and belt tension need to be tested.

909.18.6 Smoke barriers. Measurements using inclined manometers or other

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approved calibrated measuring devices shall be made of the pressure differences across smoke barriers.

Such measurements shall be conducted for each possible smoke control condition.

♦As discussed in Section 909.5.1, the testing of pressure differences across smoke barriers needs to be measured in the smoke control mode. As noted in Section 909.18.6, such testing is to be performed for every possible smoke control condition, and the measurements will be taken using an inclined manometer or other approved methods. Electronic devices are also available. Qualified individuals must calibrate these types of devices. Additionally, before using an alternative method of testing, the fire code official needs to approve such a method.

909.18.7 Controls. Each smoke zone equipped with an automatic-initiation device shall be put into operation by the actuation of one such device. Each additional device within the zone shall be verified to cause the same sequence without requiring the operation of fan motors in order to prevent damage.

Control sequences shall be verified throughout the system, including verification of override from the fire-fighter's control panel and simulation of standby power conditions.

♦This section requires the overall testing of the system. More specifically, each zone needs to individually initiate the smoke control system by the activation of an automatic initiation device. Once that has occurred, all other devices within each zone need to be verified that they will activate the system, but to avoid damage, the fans do not need to be activated.

In addition to determining that all the appropriate devices initiate the system, it must also be verified that all of the controls on the fire-fighter control panel initiate the appropriate aspects of the smoke control system, including the override capability.

Finally, the initiation and availability of the standby power system need to be verified.

909.18.8 Special inspections for smoke control. Smoke control systems shall be tested by a special inspector.

♦Smoke control systems require special inspection since they are unique and complex life safety systems.

Section 1704.16 of the IBC provides the same requirements for special inspection as presented in Sections 909.18.8.1 and 909.18.8.2.

909.18.8.1 Scope of testing. Special inspections shall be conducted in accordance with

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the following:

1. During erection of ductwork and prior to concealment for the purposes of leakage testing and recording of device location.

2. Prior to occupancy and after sufficient completion for the purposes of pressure-difference testing, flow measurements, and detection and control verification.

♦Special inspections need to occur at two different stages during construction to facilitate the necessary inspections. The first round of special inspections occurs before concealment of the ductwork or fire protection elements. The special inspector needs to verify the leakage as noted in Section 909.10.2. Additionally, the location of all fire protection devices needs to be verified and documented at this time.

The second round of special inspections occurs just prior to occupancy. The inspections include the verification of pressure differences across smoke barriers as required in Sections 909.18.6 and 909.5.1, the verification of appropriate volumes of airflow as noted in the design and finally the verification of the appropriate operation of the detection and control mechanisms as required in Sections 909.18.1 and 909.18.7. These tests need to occur just prior to occupancy, since the test result will more clearly represent actual conditions. This also makes a robust design and quality assurance during construction critical as it is very costly and difficult in most cases to make changes at this stage. Note that the test does not actually place smoke into the space and demonstrate the smoke layer interface location. Instead, the testing is focused on all the elements of the design such as airflow and duct closure as prescribed by the specific design.

909.18.8.2 Qualifications. Special inspection agencies for smoke control shall have expertise in fire protection engineering, mechanical engineering and certification as air balancers.

♦As noted in Section 909.3, special inspections are required for smoke control systems. This means a certain level of qualification that would include the need for expertise in fire protection engineering, mechanical engineering and certification as air balancers.

909.18.8.3 Reports. A complete report of testing shall be prepared by the special inspector or special inspection agency. The report shall include identification of all devices by manufacturer, nameplate data, design values, measured values and identification tag or mark. The report shall be reviewed by the responsible registered design professional and, when satisfied that the design intent has been achieved, the

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responsible registered design professional shall seal, sign and date the report.

♦Once the special inspections are complete, documentation of the activity is required. This documentation is to be prepared in the form of a report that identifies all devices by manufacturer, nameplate data, design values, measured values and identification or mark.

909.18.8.3.1 Report filing. A copy of the final report shall be filed with the fire code official and an identical copy shall be maintained in an approved location at the building.

♦The report needs to be reviewed, approved and then signed, sealed and dated. This report is to be provided to the building official and a copy is also to remain in the building in an approved location. When a fire command center is required this is the best location for such documents. Otherwise, a location such as the security office or building manager's office might be appropriate.

909.18.9 Identification and documentation. Charts, drawings and other documents identifying and locating each component of the smoke control system, and describing their proper function and maintenance requirements, shall be maintained on file at the building as an attachment to the report required by Section 909.18.8.3. Devices shall have an approved identifying tag or mark on them consistent with the other required documentation and shall be dated indicating the last time they were successfully tested and by whom.

♦Additional documentation that needs to be maintained includes charts, drawings and other related documentation that assists in the identification of each aspect of the smoke control system. This documentation is where information, such as the last time a device or component was successfully tested and by whom, is recorded. This will serve as the main documentation for the system. Again, the fire command center, if required, is the most appropriate location for such information (see commentary, Section 909.18.8.3.1).

909.19 System acceptance. Buildings, or portions thereof, required by this code to comply with this section shall not be issued a certificate of occupancy until such time that the fire code official determines that the provisions of this section have been fully complied with and that the fire department has received satisfactory instruction on the operation, both automatic and manual, of the system and a written maintenance program complying with the requirements of Section 909.20.1 has been submitted

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and approved by the fire code official.

Exception: In buildings of phased construction, a temporary certificate of occupancy, as approved by the fire code official , shall be allowed, provided that those portions of the building to be occupied meet the requirements of this section and that the remainder does not pose a significant hazard to the safety of the proposed occupants or adjacent buildings.

♦This section stipulates that the certificate of occupancy cannot be issued unless the smoke control system has been accepted. It is essential that the system be inspected and approved since it is a life safety system. There is an exception for buildings that are constructed in phases where a temporary certificate of occupancy is allowed. For example, a building where the portion requiring smoke control is not yet occupied so egress concerns through that space are not relevant. This space needs to be separated by smoke barriers (different smoke zone). The code also requires a maintenance program for smoke control systems since the long-term success of such systems depends heavily on proper maintenance in addition to rigorous acceptance testing. The IBC simply provides a reference to that section of the code.

909.20 Maintenance. Smoke control systems shall be maintained to ensure to a reasonable degree that the system is capable of controlling smoke for the duration required. The system shall be maintained in accordance with the manufacturer's instructions and Sections 909.20.1 through 909.20.5.

♦Routine maintenance and testing of smoke control systems is essential to ensure their performance, as designed, under fire conditions. Maintenance practices must be consistent with the manufacturer's recommendations and as indicated in Sections 909.20.1 through 909.20.5. Note that Section 909.12 requires weekly preprogrammed tests which report abnormal conditions.

909.20.1 Schedule. A routine maintenance and operational testing program shall be initiated immediately after the smoke control system has passed the acceptance tests. A written schedule for routine maintenance and operational testing shall be established.

♦Operational testing and maintenance must be performed on the smoke control system periodically to verify that it still operates as required by the approved design. A written schedule complying with Section 909.12.2 must be maintained.

909.20.2 Written record. A written record of smoke control system testing and

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maintenance shall be maintained on the premises. The written record shall include the date of the maintenance, identification of the servicing personnel and notification of any unsatisfactory condition and the corrective action taken, including parts replaced.

♦This section prescribes the desired content of the written record for the smoke control testing and maintenance program. Test results and maintenance activities should be clearly documented. The written record should be available for inspection and reviewed by the fire code official.

909.20.3 Testing. Operational testing of the smoke control system shall include all equipment such as initiating devices, fans, dampers, controls, doors and windows.

♦Smoke control systems are made up of components and equipment that are an integral part of other building systems such as fire alarm systems, heating, ventilating and air-conditioning (HVAC) equipment and automatic sprinkler systems. For this reason, operational testing of all related system components must ensure that the system as a whole will perform as intended.

909.20.4 Dedicated smoke control systems. Dedicated smoke control systems shall be operated for each control sequence semiannually. The system shall also be tested under standby power conditions.

♦Because dedicated smoke control systems are designed for smoke control only, the operation of these systems does not adversely affect other building systems or operations. The control sequence for these systems must be tested semiannually to check for system component failures that may not get noticed because dedicated smoke control systems are independent of building HVAC systems.

909.20.5 Nondedicated smoke control systems. Non-dedicated smoke control systems shall be operated for each control sequence annually. The system shall also be tested under standby power conditions.

♦Contrary to dedicated smoke control systems identified in Section 909.20.4, smoke control systems that are not dedicated share system components with other building systems including the HVAC system.

Consequently, testing of the control sequence of systems that are not dedicated can be done annually, rather than semiannually, because equipment failures related to other building systems would most likely be noticed and corrected when those other systems were tested or maintained.

Simply because a system is

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nondedicated does not guarantee that failures will be detected easier. This relates to the fact that when a system is in smoke control mode it may have very different demands than when simply operating as a traditional HVAC system (see commentary, Section 909.12).

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